Archives of Orthopaedic and Trauma Surgery (2019) 139:709–716
https://doi.org/10.1007/s00402-019-03157-z

KNEE ARTHROPLASTY

Simultaneous vs staged bilateral total knee arthroplasty: a propensity-matched case–control study from nine fast-track centres

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Received: 31 October 2018 / Published online: 6 March 2019

Abstract

Introduction Limited data exist on patient safety after simultaneous vs staged bilateral total knee arthroplasty (TKA) in matched groups. Hence, the aim of this study was to compare length of stay (LOS), in-hospital complications, 30-day readmissions and mortality after simultaneous and staged bilateral TKA in matched patients.

Patients and methods A retrospective case–control study of prospectively collected data in nine centres from February 2010 to November 2015. Propensity scores (PS) were used to match simultaneous and staged (1–6 months between stages) bilateral TKA patients with prospectively collected patient characteristics from the Lundbeck Foundation Centre for Fast-track THA and TKA Database. 30-day follow-up was acquired from the Danish Patient Registry and patient records.

Results A total of 344 (47.1%) simultaneous and 386 (52.9%) staged bilateral TKA procedures were performed. PS matching was possible in 232 simultaneous and 232 staged bilateral TKA patients. LOS was median 4 days (IQR 3–5) after simultaneous and cumulated 4 days (IQR 4–6) after staged procedures. The in-hospital complication rate was 15.5% after simultaneous vs 7.3% ($p=0.004$) after staged procedures. Two cases (0.9%) of venous thromboembolic events were found in each group. Eight patients (3.4%) were re-operated after simultaneous vs one patient (0.4%) after staged bilateral TKA ($p=0.037$). The 30-day readmission rate was 8.6% after simultaneous vs 5.6% after staged procedures ($p=0.281$). No patients died in either group.

Conclusions We found no significant differences in 30-day readmission rates and mortality between simultaneous and staged bilateral TKA, but the in-hospital complication rate and re-operation rate was higher after the simultaneous procedure calling for further matched investigations in larger cohorts.

Keywords Total knee arthroplasty · Bilateral · Simultaneous · Staged · Fast-track · Case–control

Introduction

About one of four patients with knee osteoarthrosis has bilateral disease at the time of surgery [1]. The indication for simultaneous bilateral total knee arthroplasty (TKA) is controversial, but potential advantages such as reduction in

The members of the Lundbeck Foundation Centre for Fast-Track Hip and Knee Replacement Collaborative Group are given in the acknowledgement section.

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costs, total rehabilitation time and total length of hospital stay (LOS) have led to an increasing number of simultaneous bilateral TKA procedures [2–5].

The fast-track methodology is a multimodal concept aiming at reducing postoperative morbidity, mortality and functional convalescence with an earlier achievement of functional milestones [6–8]. In this perspective, it is ideal to offer the simultaneous bilateral procedure instead of a staged procedure. However, only if the simultaneous procedure is as safe as the staged alternative. Promising results with low postoperative morbidity and mortality after fast-track simultaneous bilateral TKA in selected patients have been reported [9–11], but without comparison to staged procedures.

No randomized controlled trial exists, and the only previous matched case–control study found no increase in postoperative complications or mortality within 90 days after simultaneous bilateral TKA [12]. The conclusions are diverging from the previous published studies comparing outcome after simultaneous and staged bilateral procedures. A large part of the studies found increased postoperative mortality and complications after simultaneous bilateral TKA compared to staged bilateral TKA, with pulmonary embolism and cardiac complications as the major complications [2, 13–17]. In contrast, other studies reported no differences in mortality and complications between simultaneous and staged procedures [3, 4, 18]. Interpretation is difficult due to the scarcity of studies with prospectively collected data and proper matching.

Hence, the aim of this study was to compare length of stay (LOS), in-hospital complications, 30-day readmissions and mortality after simultaneous and staged bilateral TKA in matched patients.

Patients and methods

This is a retrospective case–control study of prospectively collected data. Data on 6897 primary TKA procedures were collected between February 2010 and November 2015 in 9 departments reporting to the Lundbeck Foundation Centre for Fast-track THA and TKA Database (LCDB) [19]. From a total of 1304 bilateral TKA procedures, only simultaneous bilateral TKA procedures (performed under the same anaesthesia) and staged bilateral TKA procedures performed with 1–6 months between stages were included. Indication for the simultaneous or staged procedure was based on patient and surgeon preference, but the recommended selection criteria for simultaneous bilateral TKA within the participating departments are painful bilateral knee osteoarthritis and no known cardiopulmonary comorbidity [9]. In total, 344 (47.1%) simultaneous and 386 (52.9%) staged bilateral TKA procedures were available for analysis with 232 of each procedure included in the PS-matched analysis (Fig. 1).

All departments have implemented the fast-track methodology, including neuroaxial anaesthesia, tranexamic acid, opioid-sparing analgesia with acetaminophen, non-steroid anti-inflammatory drugs (NSAIDs), and early mobilization, regardless of age or preexisting comorbidity. Patients were discharged to home and thrombosis prophylaxis was low-molecular weight heparin or factor Xa-inhibitors only during hospitalization when LOS ≤ 5 days [20]. Patients in both groups were discharged when functional discharge criteria were met. The discharge criteria included being able to undertake independent personal care, being able to walk with or without crutches, being able to get in and out of bed, and being able to get up independently from a chair or toilet [6, 9]. The LCDB contains detailed data on preoperative comorbidity and patient characteristics (Table 1). Data are prospectively collected from patients within 1 month before surgery using patient-reported questionnaires with staff available for assistance [21].

In a fast-track setting, a LOS > 4 days after primary TKA is considered as prolonged and indicative for potential in-hospital complications [21, 22]. Therefore, all patients with a LOS of > 4 days had their medical records examined to determine the reason for prolonged LOS. All the patients with a LOS of > 4 days had their medical records examined to determine the reason for prolonged LOS. Using the patients' unique Danish social security numbers (Central Office of Civil Registration), we obtained information on 30-day readmissions from the Danish National Patient Registry (DNPR) [23]. As reporting to the DNPR is mandatory for hospitals to receive reimbursement, almost complete follow-up (> 98.5%) is assured [24]. All unplanned admissions with an overnight

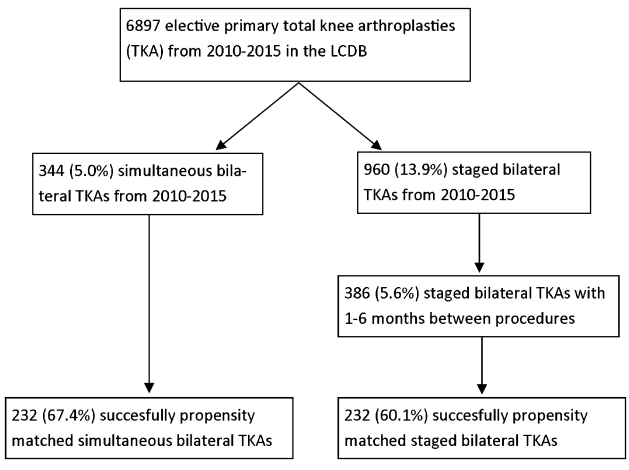

Fig. 1 Flowchart of the study population. *LCDB* the Lundbeck Foundation Center for Hip and Knee Replacement Database

Table 1 Preoperative characteristics in the complete and in the propensity-matched cohort

Preoperative characteristics *n* (%)	Simultaneous bilateral TKA *n* = 344	Staged bilateral TKA *n* = 386	Simultaneous bilateral TKA PS matched *n* = 232	Staged bilateral TKA PS matched *n* = 232	STD
Age mean (range)	63.2 (41–86)	67.7 (36–90)	64.6 (41–86)	65.0 (36–90)	0.0303
< 50	22 (6.4)	12 (3.1)	11 (4.7)	11 (4.7)	0
50–60	94 (27.3)	66 (17.1)	49 (21.9)	51 (22.0)	0.0179
61–65	83 (24.1)	71 (18.4)	60 (25.9)	54 (23.3)	− 0.050
66–70	74 (21.5)	84 (21.8)	50 (21.6)	54 (23.3)	0.033
71–75	53 (15.4)	82 (21.2)	44 (19.0)	47 (20.3)	0.027
76–80	14 (4.1)	45 (11.7)	14 (6.0)	13 (5.6)	− 0.1014
81–85	3 (0.9)	19 (4.9)	3 (1.3)	1 (0.4)	− 0.088
> 85	1 (0.3)	7 (1.8)	1 (0.4)	1 (0.4)	0
BMI mean (range)	29.7 (18.8–55.1)	31.2 (19.1–56.7)	30.5 (18.8–55.1)	30.8 (19.1–56.7)	0.054
< 18.5					
18.5–24.9	55 (16.0)	47 (12.2)	28 (12.1)	26 (11.2)	− 0.023
25.0–29.9	144 (41.9)	132 (34.2)	89 (38.4)	95 (40.9)	0.042
30.0–34.9	93 (27.9)	110 (28.5)	70 (30.2)	63 (27.2)	− 0.054
35.0–39.9	34 (9.9)	63 (16.3)	29 (12.5)	28 (12.1)	− 0.010
> 40	18 (5.2)	33 (8.5)	16 (6.9)	20 (8.6)	0.051
Missing	0	1 (0.3)			
Female gender	161 (46.8)	224 (58.0)	124 (53.4)	123 (53.0)	− 0.007
Living alone	78 (22.7)	131 (33.9)	59 (25.4)	58 (25.0)	− 0.008
Missing	1 (0.3)	3 (0.8)			
Walking aid	40 (11.6)	101 (26.2)	37 (15.9)	37 (15.9)	0
Missing	2 (0.6)	5 (1.3)			
Smoking	39 (11.3)	43 (11.1)	25 (10.8)	25 (10.8)	0
Missing	1 (0.3)	0			
Alcohol > 2 units/day	39 (11.3)	36 (9.3)	22 (9.5)	26 (11.2)	0.045
Missing	1 (0.3)	1 (0.3)			
Type 2 diabetes	25 (7.3)	57 (14.8)	22 (9.5)	23 (9.9)	0.011
Missing	0	1 (0.3)			
Cardiovascular disease	19 (5.5)	58 (15.0)	19 (8.2)	22 (9.5)	0.037
Missing	3 (0.9)	2 (0.5)			
Pulmonary disease	17 (4.9)	34 (8.8)	12 (5.8)	9 (3.9)	− 0.052
Missing	3 (0.9)	1 (0.3)			
Previous cerebral attack	13 (3.8)	25 (6.5)	11 (4.7)	11 (4.7)	0
Missing	2 (0.6)	2 (0.5)			
Previous VTE	14 (4.1)	23 (6.0)	13 (5.6)	16 (6.9)	0.043
Missing	4 (1.2)	6 (1.6)			
Preoperative anaemia	28 (8.1)	48 (12.4)	18 (7.8)	17 (7.8)	0
Missing	0	3 (0.8)			
Hypertension	167 (48.5)	220 (57.0)	117 (50.4)	124 (53.4)	0.049
Missing	0	2 (0.5)			

BMI body mass index, *VTE* venous thromboembolism, *PS matched* propensity score matched, *STD* standardized difference > 0.10 chosen a priori as indicative of imbalance

hospital stay < 30 days postoperatively were evaluated using discharge records or patient records and were included as readmissions if potentially related to index surgery.

Simultaneous and staged bilateral TKA patients were compared using 1:1 PS matching discarding any patients outside the area of common support. The patients were matched using a nearest neighbour match with a calliper of

0.2 on all comorbidities and characteristics registered in the LCDB and excluding patients with missing data on any variable (Table 1). Distribution of preoperative characteristics in the propensity-matched population was evaluated using the standardized differences (STD) [25], with a STD of > 0.100 chosen as indicative of imbalance. Means with ranges are reported for normally distributed data and proportions are expressed as percentages. Crude comparisons of proportions of non-matched patients were done using a Chi-squared test and comparisons of PS-matched patients were done using McNemars test [25]. Any p value of <0.05 was considered significant. Analysis was done using SPSS version 20.

Ethics

The National Ethics Committee waived the need for approval, as this was an observational non-interventional study. Permission was acquired from the Danish Data Protection Agency and the Danish National Board of Health to review and store all data and medical records. The LCDB is registered on ClinicalTrials.gov (NCT01515670) as an ongoing study registry on preoperative patient characteristics and postoperative morbidity.

Results

Total cohort (344 simultaneous bilateral TKA vs 386 staged bilateral TKA)

Median LOS was 4 days (interquartile range (IQR) 3–5) after simultaneous bilateral TKA and cumulated median 4 days (IQR 4–6) after staged bilateral TKA. Ninety-one patients (26.5%) had a LOS > 4 days after simultaneous bilateral TKA vs cumulated 36 (9.3%) after bilateral staged TKA (7 patients had a LOS > 4 days after both surgeries) (Chi-squared $p = 0.002$) (Table 2). When subtracting patients with LOS > 4 days, but without registered complication, the in-hospital complication rate was 13.4% ($n = 46$) after simultaneous staged TKA vs 7.5% ($n = 29$) after staged bilateral TKA (Chi-squared $p = 0.009$). The 30-day readmission rate was 7.3% after simultaneous vs cumulated 8.0% after staged bilateral TKA (Chi-squared $p = 0.699$). No patients died within 30 days postoperatively (Table 3).

Table 2 Postoperative in-hospital complications causing LOS > 4 days in the total cohort of 344 simultaneous bilateral TKA vs 386 staged bilateral TKA patients

Causes of LOS > 4 days	Simultaneous bilateral TKA $n = 91$ (26.5%)	Staged bilateral TKA (first stage) $n = 25$ (6.5%)	Staged bilateral TKA (second stage) $n = 18$ (4.7%)
Surgically related	5 (1.5)	0	
TKA dislocation (re-operated)	2 (0.6)		
Patella dislocation (re-operated)	1 (0.3)		
Periprosthetic femoral fracture (re-operated)	1 (0.3)		
Patella tendon rupture (re-operated)			1 (0.3)
Haematoma	1 (0.3)		1 (0.3)
Medically related	41 (11.9)	18 (4.7)	12 (3.1)
DVT/PE	1 (0.3)	1 (0.3)	
DVT suspected, but not found	1 (0.3)		
Cardiac complications		3 (0.8)	2 (0.5)
Pneumonia	2 (0.6)	1 (0.3)	1 (0.3)
Gastrointestinal complications	2 (0.6)	6 (1.6)	
Urologic/renal	2 (0.6)	1 (0.3)	4 (1.0)
Delirium	2 (0.6)		
Anaemia	13 (3.8)	1 (0.3)	1 (0.3)
PONV/opioid side effects	4 (1.2)	1 (0.3)	
Sepsis (unknown focus)		1 (0.3)	
Pain and prolonged mobilization	14 (4.1)	3 (0.8)	3 (0.8)
Uncontrolled diabetes			1 (0.3)
No recorded cause	45 (13.1)	7 (1.8)	4 (1.0)

Seven patients having staged bilateral TKA had LOS > 4 days after both staged procedures

PONV postoperative nausea and vomiting, *DVT* deep venous thrombosis, *PE* pulmonary embolism

Table 3 Readmissions within 30 days postoperatively in the total cohort of 344 simultaneous bilateral TKA vs 386 staged bilateral TKA patients

Readmissions 1–30 days	Simultaneous bilateral TKA $n=25$ (7.3%)	Staged bilateral TKA $n=31$ (8.0%)
Surgically related	9 (2.6)	7 (1.8)
Infection (re-operated)	5 (1.5)	
Infection suspected, but not found	2 (0.6)	4 (1.0)
Haematoma	1 (0.3)	
Wound oozing (re-operated)	1 (0.3)	
Wound oozing (not re-operated)		2 (0.5)
Wound rupture + infection (re-operated)		1 (0.3)
Medically related	16 (4.7)	24 (6.2)
DVT/PE	2 (0.6)	2 (0.5)
DVT suspected, but not found	1 (0.3)	9 (2.3)
Cardiac complications	1 (0.3)	
Pneumonia		1 (0.3)
Gastrointestinal complications	4 (1.2)	2 (0.5)
Urologic/renal complications	3 (0.9)	1 (0.3)
Anaemia	1 (0.3)	3 (0.8)
Rehabilitation (including pain)	2 (0.6)	2 (0.5)
Opioid side effects	2 (0.6)	
Erysipelas		2 (0.5)
Fall		2 (0.5)

DVT deep venous thrombosis, *PE* pulmonary embolism

PS-matched cohort (232 simultaneous bilateral TKA vs 232 staged bilateral TKA)

Median LOS was 4 days (IQR 3–5) after simultaneous bilateral TKA and cumulated 4 days (IQR 4–6) after staged bilateral TKA. Sixty-eight patients (29.3%) had a LOS > 4 days after simultaneous bilateral TKA vs 18 (7.8%) after staged bilateral TKA (3 of the patients had a LOS > 4 days after both surgeries) (McNemar $p < 0.001$) (Table 4). When subtracting patients with LOS > 4 days, but without registered complication, the in-hospital complication rate was 15.5% ($n = 36$) after simultaneous bilateral TKA vs 7.3% ($n = 17$) after staged bilateral TKA (McNemar $p = 0.004$). Eight patients (3.4%) were re-operated after simultaneous vs one patient (0.4%) after staged bilateral TKA (McNemar $p = 0.037$) (Table 4). The 30-day readmission rate was 8.6% ($n = 20$) after simultaneous TKA vs 5.6% ($n = 13$) after staged bilateral TKA (McNemar $p = 0.281$). The most frequent reasons for readmissions within 30 days after simultaneous bilateral TKA were "deep infection" ($n = 4$, 1.7%) and "gastro-intestinal complications" ($n = 4$, 1.7%) whereas "suspected DVT, but not found" ($n = 5$, 2.2%) was the most frequent reason for readmission after staged bilateral TKA (Table 5).

Discussion

We were unable to demonstrate any significant differences in 30-day readmission rates and mortality between simultaneous and staged bilateral TKA in matched and non-matched analyses reflecting reasonable selection of patients to the simultaneous procedure. This is in line with the findings of the only other previous case–control study [12] and suggests that the simultaneous bilateral TKA procedure may be as safe as the staged bilateral procedure when patients are carefully selected. There were few patients with cardiopulmonary comorbidity amongst simultaneous bilateral TKA patients suggesting considerable compliance with recommended selection criteria (painful bilateral knee osteoarthritis and no known cardiopulmonary comorbidity) [9] for simultaneous bilateral TKA within the participating departments.

However, there were significantly more in-hospital complications causing LOS > 4 days after the simultaneous bilateral TKA procedure. Furthermore, there were more surgically related serious complications after the simultaneous procedure such as deep infections ($n = 4$), prosthesis dislocations ($n = 3$) and periprosthetic femoral fracture ($n = 1$) all causing re-operations. While the first finding may be attributed to twice the risk of a unilateral operation and longer OR times, the latter two findings are hardly related to the simultaneous bilateral procedure itself. However, these

Table 4 Postoperative in-hospital complications causing LOS > 4 days in 232 simultaneous bilateral TKA vs 232 staged bilateral TKA propensity-matched patients

Causes of LOS > 4 days	Simultaneous bilateral TKA $n = 68$ (29.3%)	Staged bilateral TKA (first stage) $n = 11$ (4.7%)	Staged bilateral TKA (second stage) $n = 10$ (4.3%)
Surgically related	4 (1.7)		2 (0.9)
TKA dislocation (re-operated)	2 (0.9)		
Patella dislocation (re-operated)	1 (0.4)		
Periprosthetic femoral fracture (re-operated)	1 (0.4)		
Patella tendon rupture (re-operated)			1 (0.4)
Haematoma			1 (0.4)
Medically related	32 (13.8)	9 (3.9)	9 (3.9)
DVT/PE	1 (0.4)	1 (0.4)	
Cardiac complications		2 (0.9)	1 (0.4)
Pneumonia	2 (0.9)		1 (0.4)
Gastrointestinal complications	1 (0.4)	2 (0.9)	
Urologic/renal	2 (0.9)	1 (0.4)	2 (0.9)
Delirium	1 (0.4)		
Anaemia	9 (3.9)	1 (0.4)	
PONV/opioid side effects	3 (1.3)		1 (0.4)
Sepsis (unknown focus)		1 (0.4)	
Pain and prolonged mobilization	13 (5.6)	1 (0.4)	2 (0.9)
Other medical complications			1 (0.4)
No recorded cause	32 (13.8)	2 (0.9)	1 (0.4)

Three patients having staged bilateral TKA had LOS > 4 days after both staged procedures

PONV postoperative nausea and vomiting, *DVT* deep venous thrombosis, *PE* pulmonary embolism

Table 5 Readmissions within 30 days postoperatively in 232 simultaneous bilateral TKA vs 232 staged bilateral TKA propensity-matched patients

Readmissions 1–30 days	Simultaneous bilateral TKA $n = 20$ (8.6%)	Staged bilateral TKA $n = 13$ (5.6%)
Surgically related	7 (3.0)	2 (0.9)
Infection (re-operated)	4 (1.7)	
Infection suspected, but not found	2 (0.9)	1 (0.4)
Haematoma	1 (0.4)	1 (0.4)
Medically related	13 (5.6)	11 (4.7)
DVT/PE	2 (0.9)	2 (0.9)
DVT suspected, but not found	1 (0.4)	5 (2.2)
Cardiac complications	1 (0.4)	
Pneumonia		1 (0.4)
Gastrointestinal complications	4 (1.7)	1 (0.4)
Urologic/renal complications	3 (1.3)	
Anaemia		1 (0.4)
Rehabilitation (including pain)	1 (0.4)	1 (0.4)
Opioid side effects	1 (0.4)	

DVT deep venous thrombosis, *PE* pulmonary embolism

findings should be kept in mind when selecting patients for the simultaneous procedure and further studies in larger cohorts addressing specific complications are needed.

When addressing the medically related complications, we found very low numbers of postoperative VTE and cardiac complications after the simultaneous procedure which is in contrast to previous findings [2, 13–17] and probably reflecting the effect of the fast-track methodology with early mobilization on the day of surgery [9]. Postoperative anaemia caused LOS > 4 days in nine cases after simultaneous bilateral TKA compared to only one case after staged bilateral TKA. This is in line with previous findings [15] and expected to be due to the larger peri-operative blood loss after simultaneous bilateral TKA compared to a unilateral procedure and this should also be kept in mind when selecting and informing patients.

A longer cumulated LOS of median 6 days after staged bilateral TKA compared to median 4 days after simultaneous bilateral TKA has previously been reported on a nationwide basis from Denmark [4]. In contrast to these findings, we found LOS of median 4 days after both the simultaneous and staged bilateral TKA procedures probably reflecting the fact that the present study is based on data only from dedicated fast-track centres. Hence, a shorter cumulated LOS as argumentation for the simultaneous procedure is not relevant in

a fast-track setting. However, the cumulated rehabilitation period post-discharge might still be shorter after the simultaneous procedure, but cannot be confirmed or affirmed in the present study. Furthermore, the quality of life may be affected more and in a longer period after the staged procedure including the interim period between stages with pain from the other knee and the presumably longer total convalescence period. Investigations of functional outcomes and quality of life in the first postoperative year after bilateral TKA should be a subject for future studies.

The relative few procedures in our study compared to the only previous case–control study [12] is a limitation and our results may be subject to a type-II error. A larger cohort is needed to draw final conclusions on specific complications after simultaneous vs staged bilateral TKA. Another limitation is the risk of reporting bias when completing the preoperative questionnaire. Although we are matching patients according to multiple preoperative characteristics, there is still a risk of selection bias as we are not able to match on other functional parameters than use of walking aid. Furthermore, specific comorbidities not registered in the preoperative questionnaire, such as rheumatoid arthritis and chronic kidney disease, should ideally have been incorporated in the propensity score which thereby may be subject to unmeasured confounding. A strength of the study includes prospective recording of numerous baseline characteristics, thus minimizing recall bias, an unselected consecutive patient population and follow-up through a high-quality nationwide register, thereby ensuring data completeness [24]. Other strengths are the standardized multicenter fast-track setup, the relative short and recent study period. Furthermore, we used staged procedures performed with an interval of 1–6 months between stages as control group to compare only with patients who could as well have been offered the simultaneous procedure. In contrast hereto, Sheth et al. [12] used staged procedures performed with an interval of 3–12 months and excluded some of the early staged procedures and included late staged patients who might not have presented with bilateral symptoms at time of first surgery.

In conclusion, we found no significant differences in 30-day readmission rates and mortality between simultaneous and staged bilateral TKA in matched and non-matched analyses. However, the higher in-hospital complication and re-operation rates after simultaneous bilateral TKA in propensity-matched analyses are calling for further investigations in larger cohorts.

Acknowledgements We thank the staff at the nine centres for the assistance with fulfilling of preoperative questionnaires from the patients. The study was sponsored by a grant from the Lundbeck Foundation (grant number: R25-A2702). The Lundbeck Foundation Centre for Fast-Track Hip and Knee Replacement Collaborative Group consists of: Frank Madsen, Department of Orthopedics, Aarhus University Hospital, Aarhus University, Aarhus, Denmark; Torben B. Hansen, Department of Orthopedics, Regional Hospital Holstebro, Aarhus University, Aarhus, Denmark; Søren Solgaard, Orthopedic Department, Copenhagen University Hospital Gentofte, Copenhagen University, Copenhagen, Denmark; Mogens B. Laursen, Orthopedic Division, Aalborg Hospital, Aalborg University, Aalborg, Denmark; Lars T. Hansen, Orthopedic Department, Sydvestjysk Hospital Esbjerg/Grindsted, Esbjerg, Denmark; Per Kjærsgaard-Andersen, Department of Orthopedics, Vejle Hospital, University of Southern Denmark, Odense, Denmark; Lars P.Jorn, Orthopedics Department, Viborg Regional Hospital, Viborg, Denmark and Jens Bagger, Department of Orthopaedic Surgery, Copenhagen University Hospital Bispebjerg, Copenhagen, Denmark.

Compliance with ethical standards

Conflict of interest The study was sponsored by a grant from the Lundbeck Foundation (Grant number: R25-A2702). No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. No conflicts of interest were declared from the authors of this study.

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